MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

TOTAL SHIP INTEGRATION OF A FREE ELECTRON LASER (FEL)

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High-power Free Electron Lasers (FELs), capable of stopping an incoming anti-ship missile, can be an effective addition to the self-defense system of a modern naval combatant. A shipboard FEL must be compact, efficient, and capable of reliable operation in a naval environment. This thesis explores the feasibility of integrating a 1 MW infrared FEL aboard a surface combatant from a Total Ship Systems perspective. A study of system aspects including prime power systems and vibrational effects will be addressed to determine the overall ship impact.

A 1 MW FEL requires about 10 MW of electrical power from the shipboard prime power system if run continuously or approximately 2 MW using energy storage. A DDG-51 Arleigh Burke class Destroyer has sufficient reserve generating capacity to produce the required electrical power for the FEL. The required prime power electrical distribution system is compatible with the ship's main propulsion gas turbines and will weigh 42900 kg and occupy 35 m^3. Shipboard vibrations which will have the greatest influence on the FEL are generally characterized at frequencies below 50 Hz and have amplitudes approaching 900μm. The effect of these vibrations can reduce to an acceptable level which will permit continuous operation in the maritime environment. From a Total Ship Systems perspective the FEL can be accommodated in a DDG-51 class destroyer with negligible impact.

ASSESSMENT OF DIESEL ENGINE CONDITION USING TIME RESOLVED MEASUREMENTS AND SIGNAL PROCESSING

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An experimental investigation was conducted to access methods of detecting, and localizing faults in a diesel engine. A three cylinder, two stroke Detroit 3-53 engine was heavily instrumented for time resolved measurements. In particular, a 3,600 count per revolution optical encoder was used along with accelerometers mounted on various engine structures, in-cylinder pressure measurements and a variety of steady state sensors, such as exhaust temperatures. A large number of baseline data were taken to establish the statistical characteristics on the signals from the engine. These runs were followed by a series of experiments where the cylinder head assembly bolt torque were varied parametrically. Standard spectral analysis and Joint Time Frequency Analysis (JTFA) were used to identify the fundamental vibration characteristics of the engine. The vibration frequencies were checked for consistency against first order models of the engine assembly and reasonable agreement was found. In addition, a new technique for accessing engine health using time of arrival of encoder signals was investigated.

THE ROLE OF PARTICLE CRACKING IN DILATATION DURING TENSILE STRAINING OF A CAST AND THERMOMECHANICALLY PROCESSED 6061 AL-20 VOLUME PERCENT AL_2O_3 METAL MATRIX COMPOSITE

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In this work, the dilatation during tensile straining of a cast and thermomechanically processed 6061 Al- Al_2O_3 metal matrix composite (MMC) containing 20 volume percent of Al_2O_3 particles was examined.

Standard tensile test samples of the MMC and unreinforced 6061 Al were machined. Precise diameter measurements were made of both composite and unreinforced samples prior to and immediately following tensile straining. Tension tests were conducted to various strains as well as to fracture and an extensometer was employed to obtain accurate measurement of the axial strain. The MMC material exhibited a continuously increasing dilatation during tensile straining while the unreinforced 6061 control material deformed plastically at constant volume.

Careful metallographic preparation revealed particle cracking in all MMC samples throughout the range of strains examined. A clear trend of increased frequency of particle cracking was observed. Void formation and growth due to cracking of the particles was analyzed and shown to correlate with the dilation observed during tensile straining of the composite. Linkage of such voids is proposed as the mechanism of crack propagation at failure of the MMC.

CONVECTIVE HEAT TRANSFER FROM A VERTICAL CYLINDER IN A HIGH AMPLITUDE RESONANT SOUND FIELD

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This thesis is part of a continuing study in developing convective heat transfer correlation's for a cylinder in a high amplitude zero-mean oscillating flow. The experiment described here utilizes the RTD technique and a steady state heat transfer measurement method with a platinum wire, serving as the test section, positioned across the inner diameter of a cylindrical Plexiglas chamber supporting a strong resonant axial acoustic field. Utilizing two different wire diameters of 0.050 mm and 0.127 mm, various pressure ratios, frequencies, and temperature differences, separated flow heat transfer correlations have been developed. This work would find application in the design of heat exchangers for a thermo-acoustic engine.

PARALLEL IMPLEMENTATIONS OF PERSPECTIVE VIEW GENERATOR RAY TRACING ALGORITHMS

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In developing line of sight target acquisition software two approaches have been explored. The first was an object based system (Young and Whitney). Next, and more recently, has been the implementation of a database driven simulation. The heart of this implementation is the Perspective View Generator (PVG) developed for the U.S. Army by Wolfgang Baer. This implementation suffers from two fundamental shortcomings: low frame rates and unrealistic representation of target vehicles. This paper concentrates on using more powerful, multi-processor work stations to improve frame rates. The paper also addresses possible methods for representing vehicles in this multi-processor environment.

PARAMETRICS OF NEAR SURFACE RESPONSE OF SUBMERSIBLE VEHICLES

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Vertical plane response of submersible vehicles in the proximity of a free surface in deep water is evaluated using a potential flow, strip theory solver. Two criteria, that are periscope submergence, and sail broaching are used to quantify the response. These criteria combined with the vehicle's response amplitude operators in regular sinusoidal waves

along with a statistical description of the seaway lead to an assessment of an overall operability index for the vehicle. This thesis presents a systematic parametric study of the effects of body geometry on near surface response. Two cases, namely limited diameter and limited length are considered. The total volume of the vehicle is kept constant, and certain shape factors are changed, while either the overall diameter or the overall length remains the same. The operability index is calculated for each case within a given range for sea states and sea directions and for various shape factors, vehicle speeds and operating depths. The results indicate that certain changes of shape factors can improve vehicle operations in various depth and speed combinations.

THE EFFECT OF VARYING THE MnO CONTENT OF THE FLUX USED FOR THE SUBMERGED ARC WELDING OF NAVY HY-100 STEEL

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Weld metal strength and toughness are determined by its microstructure, which is in turn determined by the concentration of various alloying elements and impurities as well as the welding thermal cycle. This study investigated the effects of systematically varying the manganese oxide content in the flux used for HY-100 submerged arc welds. A trial addition of cerium oxide was also performed. Specimens were compared using mechanical properties, weld metal chemistry, inclusion chemistry, and microstructural analysis. It was found that cerium oxide addition and the correct amount of manganese oxide resulted in improved toughness. These improved properties were determined to arise from a low proportion of bainite in the fully reaustenitized region of the weld metal HAZ in these multipass welds. In the MnO series welds, the bainite is replaced by a fine low carbon martensite due to the increased weld metal hardenability. In the CeO_2 weld it is replaced by acicular ferrite due to the lowering of the austenite grain boundary energy by the cerium. The production of a series of welds with different manganese contents also resulted in the extension of existing theories of weld metal deoxidation.

COMPARATIVE DESIGN ANALYSIS OF A FUEL CELL POWERED COAST GUARD CUTTER

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This investigation studied the impact of using fuel cells as the primary power source in a ship design. Three different fuel cells were modeled: Phosphoric Acid, Proton Exchange Membrane, and Molten Carbonate. These models were compared against a baseline design containing a more conventional power plant. The models were built and optimized using the “Advanced Surface Ship Evaluation Tool” (ASSET/MONOSC). Specifically, payload, endurance, sustained speed, and hull depth were held constant, while length, beam, and draft were optimized to provide a balanced design. Full load displacement and required fuel load were compared against the baseline values. Conclusions concerning the potential value of a fuel cell power plant were drawn.

ANALYTICAL ANALYSIS OF TIP TRAVEL IN A BOURDON TUBE

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Bourdon tubes are the most commonly used elastic elements in mechanical pressure gauges. Basic theory describing the principles of Bourdon behavior is readily available but very few analytical studies have been published that model Bourdon element behavior. The purpose of this research is to develop an analytical model to determine tip displacement in tubular elastic elements using basic principles of solid mechanics. To determine the validity of the results obtained from the analytical model, a study of results from finite element solutions and experimental data is also present.

SIMPLIFIED FINITE ELEMENT MODELING OF STIFFENED CYLINDERS SUBJECTED TO UNDERWATER EXPLOSION

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Simplified finite element modeling of a stiffened cylinder subjected to underwater explosion was investigated. The use of smearing the stiffeners into the base structure as well as beam modeling using SOR (Surface of Revolution) beam elements were used in the model simplification process. The dynamic response and overall global deformation were then compared between the fully discretized stiffened cylinder model and the simplified models. The study first examined the effectiveness of smearing stiffeners into a flat plate. The smearing of stiffeners into a cylindrical shell orthotropically was then examined. Next, beam modeling of both unstiffened and stiffened cylinders was investigated. Finally an integrated beam/shell model of a stiffened cylinder was developed. These models were subjected to the same underwater explosive loading for numerical study. The analysis showed that when comparing the dynamic responses caused by underwater explosions between the discrete model, the beam model, and the beam/shell model of a stiffened cylinder, globally similar results could be produced.

WAVE/CURRENT INDUCED FORCES ON CIRCULAR CYLINDERS

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The numerical simulations of oscillating plus mean flow past a circular cylinder have been carried out in detail through the use of a commercially available software produced by CFDRC, running on a Silicon Graphics Inc. Indigo 2 Extreme computer. The Reynolds number, Keulegan-Carpenter number, and relative current velocity were systematically varied. Sensitivity analysis was performed to delineate the effects of time step, turbulence model and numerical schemes. The results have been compared to those obtained experimentally and to those predicted by the Morison Equation. In many cases the predicted force coefficients have shown good agreement with those obtained experimentally.

INTERACTION OF A SWIRLING JET WITH A FREE SURFACE

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The turbulent flow field of a swirling jet issuing from a nozzle, beneath and parallel to a free surface has been studied in as much detail as possible using a three-component laser Doppler velocimeter and flow visualization. The results have shown that the swirl leads to the faster spreading and quicker mixing of the jet. For strongly swirling jets (S = 0.522), the similarity is not reached within ten diameters downstream. The results have also shown that both the axial and tangential velocity components decrease outward from the jet axis, naturally leading to centrifugal instabilities. This, in turn, leads to the creation of large scale coherent structures at the periphery of the jet, particularly when it is in the vicinity of the free surface. The turbulent shear stresses exhibit anisotropic behavior, the largest always being in the plane passing through the jet axis. The change of TKE with S is not monotonic. It is maximum for S = 0.265, smallest for S = 0.50, and has an intermediate value for S = 0.522. This is due to the occurrence of vortex breakdown and the resulting intensification of the turbulence within the jet prior to its exit from the nozzle.

FACTORS AFFECTING THE IMPACT TOUGHNESS OF ULTRA LOW CARBON STEEL WELD METAL

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The fundamental factors affecting the impact toughness of four gas metal are welds (GMAW) made on HSLA-100 base plate using a newly developed steel weld wire were studied. The weld metal analysis included chemistry, mechanical testing (hardiness, CVN/FATT), as well as optical, scanning and transmission electron microscopy. Studies of inclusion composition using energy dispersive x-ray (EDX), and electron energy loss spectroscopy (EELS) in the transmission electron microscope were also performed.

It was found that increasing oxygen content of the weld metal (due to increased oxygen in the shielding gas) led to increased non-metallic inclusion size and volume fraction; which in turn, led to both decreasing strength and toughness. The strength was lowered because increasing oxygen in the shielding gas led to increased ‘consumption’ of strengthening alloys such as carbon, manganese and silicon. The toughness was compromised by the increasing size and number of oxide inclusions as these provide sites for void formation and subsequent fracture.

THE INSTRUMENTATION DESIGN AND CONTROL OF A T63-A-700 GAS TURBINE ENGINE

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A T63-A-700 gas turbine engine has been instrumented to measure performance parameters. Pressure and temperature monitoring systems have been designed, fabricated, and installed to ensure accurate measurement of performance parameters. All measured parameters have been compared against predicted thermodynamic cycle analysis. Design and control of selected engine systems have been modified to incorporate more precise engine control and safety.

NUMERICAL ANALYSIS OF OSCILLATING FLOW ABOUT A CIRCULAR CYLINDER

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The numerical experiments, carried out through the use of a pressure-velocity coupled method to solve the Favre Averaged Navier-Stokes equations, on steady and sinusoidally oscillating flows at five different Keluegan-Carpenter numbers, and three periodicity levels are described. A second-order in time, second-order in space, second-level predictor-corrector finite difference scheme has been used. The solutions were solved by the CFD-ACE program from the CFD Research Corporation. The analysis has produced in-line force coefficients comparable to those obtained experimentally for sinusoidally-oscillating flows.

CONVECTIVE HEAT TRANSFER FROM A CYLINDER IN A STRONG ACOUSTIC FIELD

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Experimental work was performed to study the convective heat transfer characteristics from a cylinder in a strong zero-mean oscillatory flow represented by an acoustic field. Two different flow regimes are discussed; that in which laminar, attached flow around the cylinder is present, and that in which instabilities, such as vortex shedding occur. The experiment utilizes a steady state measurement method. A transition from the laminar to the unstable regime was observed to occur at a streaming Reynolds number of approximately 240. Within the laminar regime, the transition from “intermediate” to “large” values of the streaming Reynolds number occurs at approximately 130. Heat transfer results for large values of the streaming Reynolds number in the laminar regime closely match the present theory (less than 13% error). Correlation’s were developed to relate the heat transfer rate to the streaming Reynolds number in the unstable regime. This work would find application in the design of heat exchangers for a engine.

PREDICTION OF HYDRODYNAMIC COEFFICIENTS UTILIZING GEOMETRIC CONSIDERATIONS

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A parametric study of a body of revolution is conducted utilizing existing semi-empirical methods for the calculation of hydrodynamic coefficients. The geometry of the body is analyzed in non-dimensional length and volume parameters. The effects of varying the nose, mid-body, and base fractions of the body on the hydrodynamic coefficients are generated and illustrated graphically. Equations for the hydrodynamic coefficients are then determined from the non-dimensional parameters. The results can be used to evaluate fundamental maneuvering characteristics early in the design phase.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

ANALYSIS OF STEAM AND HYDRONIC COMPARTMENT HEATING SYSTEMS ABOARD U.S. COAST GUARD 140 FOOT WTGB CLASS CUTTERS

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The compartment heating system on the U.S. Coast Guard's Ice breaking Tug (WTGB) class cutter was studied to determine heat transfer performance characteristics of existing heat exchangers when used with circulating hot water vice steam. Characterizations such as Reynolds number vs. Colburn *j* factor plots, convection coefficients, overall coefficients, and Effectiveness-NTU relations were generated. Initial analysis with acknowledged conservative definitions of air side convection coefficients determined that the hydronic system provided on average seventy percent of the heat transfer capabilities available with the steam system. Improvements to the hydronic system were shown to increase heat exchanger performance parameters by an average of ten percent. It was notable that the added heat transfer available from steam is not due to a property of steam itself such as latent phase change effects, but is due solely to the increase in entering tube side temperature. Judging by heat transfer capabilities alone, with the described conservative assumptions on which these results are based, use of currently installed heat exchangers in a hydronic system is a viable option.

RESISTIVITY MEASUREMENT BY EDDY CURRENT METHODS FOR REAL-TIME MONITORING OF AGE HARDENING IN HEAT TREATABLE ALLOYS

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In this research, the design of an eddy current sensor system that continuously monitors age hardening during aging of heat treatable alloys was modified to allow for operation at temperatures up to 595°C. With two eddy current coils in an impedance bridge circuit, eddy currents are generated in a pure aluminum reference sample standard and an age hardenable test sample. The difference in the resistivity of the aging test sample relative to the reference sample results in a bridge unbalance voltage, ÐV_{BCA}, which is continuously measured by a multimeter. Also, calibration procedures were developed to allow conversion of the values of ÐV_{BCA} to a resistivity difference, Ð$\rho = \rho_{test} - \rho_{ref}$, between the test and reference samples. These calibration curves were generated by measuring ÐV_{BCA} at various temperatures for six test samples standards of known resistivity. The resistivity of the aging sample is determined by adding the known resistivity value for pure aluminum to Ðρ. Real-time monitoring of an aging alloy's resistivity may allow heat treaters to integrate this monitoring system with a control system to achieve "intelligent heat treating".

FREQUENCY DOMAIN STRUCTURAL IDENTIFICATION

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The Structural Synthesis Transformation is used to conduct structural system identification in the frequency domain. For spatially complete cases where each of the frequency response functions at every degree of freedom of each of the coordinates of the modeled system are available it is shown that the theory exactly identifies all modeling errors. For spatially incomplete cases where the frequency response functions are available only at a proper subset of the degrees of freedom of the finite element model, single mode solutions are computed over intervals about the modes of the

experimental system using matrices and complex valued line integrals. Methods of forming multiple mode solutions from the single mode solutions are explored.

THE EFFECT OF A NOVEL COATING TECHNIQUE ON FILMWISE AND DROPWISE CONDENSATION OF STEAM ON HORIZONTAL TUBES

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Steam condensation heat transfer on smooth horizontal tubes and on a Korodense horizontal tube was experimentally studied at a atmospheric pressure and at vacuum. The overall heat transfer coefficient was measured and the outside heat transfer coefficient was determined from the modified Wilson Plot Technique. A hydrophobic coating of a self-assembling monolayer (SAM) with a composition of HS $(CH_2)_{15}CH_3$ promoted excellent dropwise condensation (DWC) on tubes. Coexisting strips with varying widths of filmwise condensation (FWC) and DWC, but at a constant area ratio of 50%, were also investigated.

Smooth tubes coated with the hydrophobic SAM produced DWC heat transfer coefficients of up to 10 times that of FWC at atmospheric conditions and up to 4 times at vacuum. The Korodense tube coated with the hydrophobic SAM produced heat transfer coefficients of up to about 3 times that of FWC at atmospheric conditions and up to about 2.5 times at vacuum. Data with coexisting strips of FWC and DWC showed that the heat transfer performance was influenced by the width of strips, size of drops, condensate turbulence and loss of drop sweeping action, indicating an optimum combination of strips may exist.

DEVELOPMENT AND ASSESSMENT OF A SHIP MANEUVERING SIMULATION MODEL

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A nonlinear maneuvering model based on ship geometric and mass properties is developed. The model can be utilized to evaluate maneuvering performance early in the design phase. This model is also used in this thesis as a benchmark in order to evaluate the accuracy of the simpler Nomoto's model. The latter is faster to simulate and is ideally suited for visual simulation studies. Results comparing the relative accuracy and speed of implementation of the two models are presented for different inputs and geometric properties. An improvement to Nomoto's model is suggested which greatly increases accuracy while maintaining high speed of real time implementation. Furthermore, a series of parametric studies is performed in order to evaluate the sensitivity of fundamental maneuvering properties in terms of basic ship geometric quantities.

MODELING OF CRACK INITIATION AND GROWTH IN SOLID ROCKET PROPELLANTS USING MACROMECHANICS AND MICROMECHANICS THEORIES

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Modeling and simulation of crack initiation and propagation in solid rocket propellant materials were conducted using both the macromechanics approach and the micromacromechanics approach. Due to their composition, the solid rocket propellant can be construed as particle reinforced composites.

The macromechanics approach entailed a numerical simulation of a finite element model to predict the crack behavior based on the damage initiation, growth, and local saturation. Its results were then compared to the experimental data. In the simulation, it was assumed that a crack forms when a damage is saturated in a localized zone. The results from the simulation were quite comparable to the experimental results, validating the method of predicting crack initiation, growth, and arrest using the concept of damage growth and saturation.

The second approach involved using a simplified micromechanical model and the damage mechanics being applied at the micromechanics level and the finite element analysis being done subsequently at the macromechanics level. In using this approach, the damage modes such as matrix cracking, interface debonding and particle cracking were explainable in an explicit, fundamental manner. Several simulations were conducted using this approach including the cases of non-uniform particle distribution. The predicted results compared well with the experimental data.

SIMULATION OF SMALL ROBOTIC VEHICLE PERFORMANCE DURING UXO GATHERING OPERATIONS USING DISCRETE EVENT CONTROL

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The subject of minefield clearance has received much attention in the last few years due to its necessity during modern war fighting, and its unavoidable inherent dangers. Clearing the battlefield of Unexploded Ordnance (UXO) is a formidable task that presently requires the risk of human life. Future strategy calls for the use of a fleet of small, inexpensive, but very capable robots to clear the battlefield of all Unexploded Ordnance. The Navy's Explosive Ordnance Disposal Technical Center has developed a "BUGS" Basic UXO Gathering System in order to examine such strategy. In support of this effort, simulations are being conducted to examine the effects of navigation, control schemes, and terrain characteristics on battlefield clearance operations.

EXPERIMENTAL STUDY OF INELASTIC STRESS CONCENTRATION AROUND A CIRCULAR NOTCH

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Experiments were conducted to determine whether energy-density relations can be used to predict elastic-plastic stresses and strains near a circular notch for 7075-T6 aluminum alloys and ARALL 4 composites. The loading conditions were tension and four-point bending. Glinka and Neuber have developed relations that predict local inelastic strain response based on the stress-strain solution for small plastic zone sizes. It has been shown that these relations are appropriate for simple tension and in-plane bending, where stress and strain are uniform through the thickness. This study investigates the application of the Glinka and Neuber relations to samples where stress/strain is not constant through the thickness. Non constant stresses/strains are the result of out-of-plane bending and laminate characteristics.

BOUNDARY CURVATURE EFFECTS ON GAS BUBBLE OSCILLATIONS IN UNDERWATER EXPLOSION

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The oscillation of a gas bubble produced as a result of underwater explosion could cause the severe whipping damage on nearby marine vehicle. The effects of rigid boundary curvatures to explosion gas bubble oscillation behavior in underwater were investigated. The analyses were conducted using a multimaterial Lagrangian-Eulerian finite element code, MSC/DYTRAN. The incident shock wave pressure, bubble pulse pressure, gas bubble radius and period were calculated for the case of detonation of a charge near the curved rigid boundary. The results were compared for the case of free field bubble oscillations.

A CHARACTERIZATION OF THE MAXIMUM BENDING STRESS OF THE SLICE HULL IN RANDOM SEAS

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A study of the effects of speed, heading and sea state on the maximum longitudinal bending stress of the SLICE Advanced Technology Demonstrator is presented. Strip Theory is applied to a model of the SLICE hull. The hull is modeled using data from a current design and with ship loading weight information for ferry operations. Stress results are based on conventional beam theory applied to the hull girder. Bending moment distributions are presented for random, fully-developed, unidirectional seas. The maximum expected bending stress is calculated for varying sea states, ship speeds, and wave directions. Operability of the SLICE based on limiting material stress is evaluated for sea states through sea state 6. The results of this study indicate that increased stiffening of the hull could be considered in the vicinity just aft of the forward pods.

EXPLORATION OF THE DAMAGE STABILITY CHARACTERISTICS OF THE TRIMARAN SURFACE COMBATANT

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The new world situation and important changes in the military policy of the United States have made it necessary to find new alternatives for warships. Affordability, high performance and excellent seakeeping, combined with a high degree of survivability, are essentials for the new century. The trimaran hull form holds promise in fulfilling future needs of Navy combatants. This thesis attempts to make an evaluation of the response of the trimaran hull under nine (9) different cases of damage stability. The specifications of the multihull correspond to a “4600 Tonnes Trimaran Warship” in the process of being evaluated by NAVSEA. Many analysis problems were encountered because of the unusual type of tumble-home hull and the “wavepiecer” shape of the bow. The results show an overall good response to a damage stability analysis. The critical case, unsurprisingly, has been found to be when one side hull is flooded and the tanks in the opposite hull are completely empty. Important conclusions and data were obtained, and future research areas are identified.

PARAMETRICS OF SUBMARINE DYNAMIC STABILITY IN THE VERTICAL PLANE

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The problem of dynamic stability of submersible vehicles in the dive plane is examined utilizing bifurcation techniques. The primary mechanism of loss of stability is identified in the form of generic Hopf bifurcations to periodic solutions. Stability of the resulting limit cycles is established using center manifold approximations and integral averaging. The hydrodynamic coefficients are calculated using existing semi-empirical methods. Parametric studies are performed with varying vehicle geometric properties. The methods described in this work could suggest ways to enlarge the submerged operational envelope of a vehicle early in the design phase.

DESIGN AND ANALYSIS OF A GAS TURBINE TEST FACILITY AIR SYSTEM

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A gas turbine test facility air system has been designed to meet specified design objectives. An analytical evaluation was performed on the air system design to verify that these design objectives were achieved. A key element of the air system is an exhaust eductor which was included in the design to provide secondary cooling air flow through the engine test cell. Two analytical models were developed to evaluate exhaust eductor performance. A one-dimensional, incompressible eductor model was developed that predicts the basic eductor performance parameters including the amount of secondary air flow drawn through the engine test cell for varying eductor configurations. This model also predicts overall air system performance parameters. An eductor computational fluid dynamics analytical model was developed that provides a more detailed analysis of the flow in the eductor.

AN INVESTIGATION OF THE EFFECTS OF SECONDARY PROCESSING ON THE FRACTURE PROPERTIES OF A SiCp-6XXX A1 COMPOSITE

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Discontinuous reinforced aluminum (DRA) composites are attractive as structural materials because of their desirable stiffness and strength to weight ratios and relative ease of manufacture. However, they typically display low tensile ductility and fracture toughness. In this work, the impact of postfabrication deformation processing and heat treatment on the fracture properties of a 17.5 vol. % SiCp reinforced Al 6092 matrix composite is investigated. Process temperature, total strain and strain rate during extrusion were varied in order to explore the feasibility of obtaining Particle Stimulated Nucleation (PSN) of recrystallization during processing, with the goal of refining the matrix grain size. Additionally, various combinations of solution and aging treatments were investigated with the aim of obtaining a number of stable matrix microstructural conditions with varying levels of composite strength and fracture toughness. A preliminary investigation of fracture mechanisms and their dependence on the matrix aging state has also been carried out using optical and scanning electron microscopy (SEM) and differential scanning calorimetry (DSC), and is reported here.

DESIGN OF AN ARTICULATED MANIPULATOR FOR ENHANCED DEXTERITY IN MINIMALLY INVASIVE SURGERY

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A current limitation in minimally invasive surgical (MIS) procedures is the lack of an articulated mechanism which will provide dexterity inside the torso while supporting a surgical tool. The tool could be a pair of scissors or an optical device such as a camera, or both. To overcome this limitation we have designed an Articulated Manipulator for Minimally Invasive Surgery (AMMIS). The AMMIS is expected to provide surgeons with improved dexterity during MIS procedures and be ideally suited for tele-surgery. This design may also be used in non-medical applications such as aviation maintenance, and engine inspection.

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE RESPONSE OF A ROTOR ACCELERATING THROUGH CRITICAL SPEED

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The rotordynamic response of an imbalanced rotor accelerating through its first lateral bending critical speed was investigated both analytically and experimentally. A two degree-of-freedom lumped mass, damping and stiffness model was developed to simulate the response of a simply supported, single disk rotor during both acceleration and deceleration. The equations of motion were then solved numerically. The computer model was used to determine the effect of acceleration rate, asymmetric stiffness and damping, and acceleration scheduling on the maximum amplitude of the response. Experimental data for a simply supported, single disk rotor accelerating at different rates were compared with the computer model. Increased acceleration rates and damping reduce the magnitude of the response. Asymmetric stiffness and acceleration scheduling can also be used advantageously to reduce the maximum amplitude of the response.

EXPERIMENTAL EVALUATION OF A LOW COST ACOUSTIC COMMUNICATION SYSTEM FOR AUVs

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As the Navy has refocused its goals towards littoral warfare, mine countermeasures have become an area of special interest. The Naval Postgraduate School is developing an autonomous underwater vehicle to map shallow water minefields—a vital role in the Navy's overall plan for mine countermeasures. A key feature of the vehicle is its low cost, and to this end it uses a commercially available system called "DiveTracker" for precise acoustic navigation and communication. This research experimentally evaluated the reliability of the DiveTracker communication system in conditions approximating those for which the vehicle is designed. It was concluded that highly reliable communication of short commands will be restricted to relatively short separation distances between nodes. The very shallow water acoustic channel is highly variant in both signal attenuation and background noise levels. The maximum range is limited by the background noise while the probability of correct message reception depends on the received signal ratio. Initial data indicates that the low cost unit under development cannot communicate beyond 500 meters with a probability of a single roundtrip success greater than 34 percent. Several options are available for its improvement.

OPTIMAL SOLUTION SELECTION FOR SENSITIVITY-BASED FINITE ELEMENT MODEL UPDATING AND STRUCTURAL DAMAGE DETECTION

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The finite element model has become the standard way in which complex structural systems are modeled, analyzed, and the effects of loading simulated. A new method is developed for comparing the finite element stimulation to experimental data, so the model can be validated, which is a critical step before a model can be used to simulate the system. An optimization process for finite element structural dynamic models utilizing sensitivity based updating is applied to the model updating and damage detection problems. Candidate solutions are generated for the comparison of experimental frequencies to analytical frequencies, with mode shape comparison used as the selection criteria for the optimal solution. The method is applied to spatially complete simulations and to spatially incomplete experimental data which includes the model validation of a simple airplane model, and the damage localization in composite and steel beams with known installed damage.

A NEW KINEMATIC MODEL FOR THE STUDY OF THE ROLE OF THE ANTERIOR CRUCIATE LIGAMENT (ACL) IN HUMAN KNEE MOTION

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A six degree of freedom model was utilized to continuously measure the motions of loaded cadaveric human knees with unconstrained motion at the tibiofemoral joint through a range of motion from zero to 110 degrees of flexion. Several conditions were studied. Loading conditions were varied to simulate the natural body forces (i.e., the normal condition) and quadriceps-deficient condition. The range of motion in which the anterior cruciate ligament (ACL) is the primary restraint to anterior tibial translation was determined. The effect of ACL insufficiency on the kinematics of the human knee was investigated by comparing the kinematics of the knee specimens in the intact state with the kinematics obtained after the ACL was surgically severed. To simplify the complex kinematics of a six degree of freedom model, the motion of the instant center of the tibiofemoral joint for each specimen was estimated using the femoral transepicondylar pin reference point. The estimated motion of the instant center of the knees in the intact state and ACL deficient state and compared to empirical observations. The importance of the motion of the instant center was then determined in pathologic knee motion. Finally, the effect of total knee replacement on kinematics was investigated.

FLUID-INTERACTION AND CAVITATION EFFECTS ON A SURFACE SHIP MODEL DUE TO AN UNDERWATER EXPLOSION

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A surface ship subjected to an underwater explosion is exposed to shock waves over a short period of time which can vary in magnitude based on charge type, size, and location. The energy of those waves impinging upon the hull is transmitted throughout the ship's structure and vital equipment. The dynamics of the shock waves also influence the fluid surrounding the outer hull of the ship, creating an area of cavitating fluid. The combination of the shock waves, bubble pulsations, and cavitating fluid induce shipwide vibrations on hull supports and mission essential equipment

which may become inoperative. In view of congressional requirements for new ship designs and systems to be shock tested, this thesis investigates the modeling of a preliminary design (Flight I) of the Arleigh Burke Destroyer (DDG 51) exposed to an underwater explosion. The effects of cavitation on one and two dimensional models is explored to determine if cavitation effects are substantially important to a three dimensional ship model. Validation of modeling underwater explosion effects upon a ship model can provide potential insight and savings in cost for future live fire testing and evaluation of the Flight IIA (DDG 79) design of the Arleigh Burke Destroyer.

AN INVESTIGATION OF THE RESISTANCE PROPERTIES OF A MODERN TRIMARAN COMBATANT SHIP BASED ON TAYLOR STANDARD SERIES AND SERIES 64

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The resistance properties and effective horsepower requirements for a trimaran being considered for SC-21 (Surface Combatant for the 21st century) are investigated. The effects on EHP due to increased side hull displacement are analyzed. Residual-resistance coefficients are obtained for side hull displacements up to 5% of the center hull's displacement. Coefficients are based on the Taylor Standard Series and Series 64 data. The effects of interference on effective horsepower requirements are discussed. The potential use of Reynolds-averaged Navier-Stokes (RANS) code is presented.

ACOUSTIC UNDERWATER NAVIGATION OF THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE USING THE DIVETRACKER SYSTEM

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Autonomous Underwater Vehicles (AUVs) require a navigation system in order to conduct useful functions. This research was an experimental investigation of the commercial DiveTracker underwater acoustic navigation system used onboard the NPS Phoenix AUV. Tests conducted with the DiveTracker system proved that the system could be used successfully in AUV navigation while submerged and revealed that more precise positioning could be obtained through postconditioning of the DiveTracker output range, rather than prefiltering.

INTEGRATED SYSTEM DAMPING AND ISOLATION OF A THREE DIMENSIONAL STRUCTURE

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Controlling the vibratory response of a mechanical system is of key importance in most modern engineering designs. Constrained viscoelastic layered damping of vibrating elements is one method that can be used for vibration reduction. This thesis deals with an integrated system damping and excitation source isolation scheme for reducing the vibration signature of a three dimensional structure. Use of a validated finite element model of the system to predict system dynamic behavior proved to be an effective method in the design of the constrained viscoelastic layered damping treatment. Direct frequency response analysis was performed on the structure with the damping treatment applied and excitation source isolated. Experiments were also performed on the structure without the damping treatment to provide reference data for comparison purposes.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

ASSESSMENT OF GRAIN REFINEMENT BY MICROTEXTURE ANALYSIS IN THERMOMECHANICALLY PROCESSED AL 2519 ALLOY

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The first part of this study involved determining the mechanism by which elevated-temperature deformation occurred for selected tensile specimens from previous research on thermomechanically processed Al 2519 alloy. Microtexture information in the form of discrete pole figures indicated that the most highly superplastic material had completely recrystallized and deformed via grain boundary sliding, whereas material that did not display superplastic behavior deformed via slip. The second part of the study was designed to achieve further refinement of the microstructure of Al 2519 using the particle stimulated nucleation (PSN) model as a guide. Using the overaging parameters of the thermomechanical process (TMP) that had yielded the greatest elongation in previous work, additional material was processed but with varying final total processing strain. The resulting material was analyzed using backscatter electron (BSE) microscopy methods to evaluate the effect of total processing strain on the average grain size. The smallest true volume grain size was associated with the material with the highest total processing strain.

HEAT TRANSFER STUDIES AND FLOW VISUALIZATION OF A RECTANGULAR CHANNEL WITH AN OFFSET-PLATE-FIN ARRAY

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The heat transfer characteristics and flow visualization of a 10X scale version of internal offset-fin plate array within the liquid flow-through module for electronics cooling were investigated experimentally using water as a cooling fluid. By varying power input settings and coolant flow rates, the heat transfer effects from the plate array to the coolant water was investigated. Additionally thermochromic liquid crystals were spray-painted onto the plate to determine the temperature distribution within the heat transfer surface, as compared to the readings from the attached thermocouples. Finally a flow visualization using the dye-injection technique was to study the flow patterns of the coolant through the fin array.

RECOVERY FACTORS IN ZERO-MEAN INTERNAL OSCILLATORY FLOWS

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High speed oscillatory flows, like high speed mean flows, are capable of inducing time-average heat transfer effects. This research involves the analytical solution of a model problem of zero-mean internal oscillatory flow, which arises from a high-intensity resonant standing acoustic wave set up across the ends of two parallel plates. The compressible form of the Navier-Stokes equations are solved, along with the equations of continuity, energy, and state, using perturbation solution and complex variable methods. MAPLE, a symbolic mathematical software tool, is utilized to find the time-averaged portion of the temperature distribution between the plates. The final heat transfer results are presented in terms of suitably defined recovery factors. The analysis is performed for varying gap widths between the plates using air as the host fluid. This work provides the fundamental explanation of the phenomenon responsible for the

thermoacoustic refrigerating effect as well as an analytical basis for determining the optimum gap width between the plates of the stack in a thermoacoustic refrigerator.

VORTEX BREAKDOWN AT Re= 130,000

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Vortex breakdown is an impressive structural change in the core of a vortex, generally liable to occur in any flow characterized by longitudinal vortices. The previous mathematical and experimental studies dealt with laminar breakdowns at Reynolds numbers less than about 10,000. The present investigation deals with a relatively high Reynolds number of 130,000 in a non-cavitating swirling flow at which a new conical-type turbulent vortex breakdown occurs. Axial and swirl velocities along the test pipe are measured with a Laser Doppler Velocimeter and used to interpret the role of vortex breakdown in changing a jet-like flow into a wake-like swirling flow with a larger core.

STUDIES ON SUBMARINE CONTROL FOR PERISCOPE DEPTH OPERATIONS

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Requirements for submarine periscope depth operations have been increased by integration with carrier battle groups, littoral operations, and contributions to joint surveillance. Improved periscope depth performance is therefore imperative. Submarine control personnel rely on a large number of analog gauges and indications. An integrated digital display system could enhance the ergonomics of the human control interface and display additional parameters. This thesis investigates the required feedbacks for robust automatic depth control at periscope depth, and thus indirectly determines the additional parameters desired for an integrated display.

A model of vertical plane submarine dynamics is coupled with first and second order wave force solutions for a particular submarine full form. Sliding mode control and several schemes of state feedback are used for automatic control. Head and beam seas at sea states three and four are investigated. The automatic control effectiveness provides insight into the indications used by the ship's control party in operations at periscope depth. One possible display system is proposed, with several additional enhancements to improve ship's safety, reduce operator fatigue, and enable accurate reconstruction of the events leading to a loss of depth control.

ASSESSMENT OF SHALLOW WATER NEAR SURFACE RESPONSE OF SUBMERSIBLE VEHICLES

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Vertical plane response of submersible vehicles in the proximity of a free surface in both deep and shallow waters is evaluated using a potential flow, strip theory solver. Three criteria, namely periscope submergence, sail broaching, and collision are used to quantify the response. These criteria combined with the vehicle's response amplitude operators in regular sinusoidal waves along with a statistical description of the seaway lead to an assessment of an overall operability index for the vehicle. The operability index is calculated within a given range for sea states and sea directions and

for various vehicle speeds and operating depths. The results indicate that a certain combination of depth and speed can lead to a significant improvement in vehicle operations.

BOILING OF HIGHLY WETTING LIQUIDS IN OSCILLATORY FLOW

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In the present study, boiling of highly wetting dielectric fluid has been investigated in an oscillating fluid environment. A piston is designed to create oscillations in the fluid and over the heated platinum wire. Because of their low surface tension, these liquids require very high superheat to initiate nucleate boiling. It is expected that the amount of necessary temperature overshoot for the onset of nucleate boiling, can be decreased with oscillation in the fluid. The oscillation can remove the bubbles, which are forming in the nucleation sites as soon as they start growing on the outer surface. This increases efficiency of nucleation sites, which are very scarce.

All of the oscillation amplitudes and frequencies, tested here, changed the boiling curve of highly wetting dielectric fluid, so that the apparent temperature overshoot has decreased. Remarkably at some oscillation amplitude and frequencies the superheat is almost vanished. The effects of the amplitudes and frequencies on the boiling curve varied because of the present bubble size and growth rate, which depend on the size of the nucleation sites.

NUMERICAL AND EXPERIMENTAL STUDY OF FAILURE OF THE HUMAN PROXIMAL FEMUR

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Static and dynamic experiments were conducted to study the failure loads and fracture patterns of human proximal femur bones, that are intact and core drilled. This was done to assist orthopedic surgeons to better understand the effects of core drilling into the femoral head to remove osteonecrosis. Unlike previous studies, where only static tests were conducted, dynamic tests were preformed to better simulate a lateral fall. A Finite Element Analysis (FEA) was also completed to understand stress distributions in the proximal femur when subjected to static and dynamic loads. Previous FEA models of the femur analyzed static loads only with just a core drilled hole at the lesser trochanter. This FEA model examines various sizes of hole diameters and locations on the greater trochanter as well as having the model loaded statically and dynamically.

DESIGN AND METHOD FOR THE EVALUATION OF THE COKING RESISTANCE OF SWIRL PLATES OF THE E-2C AIRCRAFT FUEL NOZZLES

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The extensive coking observed on the swirl plates of the fuel nozzles of the E-2C HAWKEYE aircraft is the initiative of this investigation. A testing rig reproducing the shut down procedure of the engine was designed and a method for the evaluation of the resistance in coking for different types of swirl plates is presented. The method is based on measurements of weight increase and holes closure, and on microscopic examination. It can be applied to the evaluation of any suggested modification of swirl plates in the future and provides the Navy with a reliable easy to use and modify experimental set-up able to produce comparative data. Results for two different types of swirl plates with

different surface finish are presented, together with conclusions and comments arising from the experimental results and the design process. Recommendations for future search objectives relative to the problem are also presented.

MAGNETIC INDUCTIVE SENSOR APPLICATIONS FOR ROBOTIC ORDNANCE DETECTION AND RECOVERY

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The use of robotic vehicles to detect and remove unexploded ordnance (UXO) from battlefields and training ranges is currently being explored by the Naval Explosive Ordnance Disposal Technical Division, Indian Head, Maryland. In support of this effort, research was conducted in the characterization and use of small, commercially available magnetic inductance sensors to detect a variety of common U.S. submunitions. Sensor test bed mounting on a small wheeled vehicle with a sweep device allowed for dynamic testing against submunitions under laboratory and field conditions.

A COMPARATIVE STUDY INTO THE COKING RESISTIVITY OF SWIRLPLATES WITH VARIOUS SURFACE FINISHES

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Gas turbine nozzle swirlplates used in the T56-A-427 engines of the E-2C Hawkeye aircraft were tested for their resistivity to fuel deposit formations, or ‘coking’. The coking occurred after the engines were shut down due to the fuel trapped in the line and temperature ranges present at the nozzle tip. As the coke built up, the holes in the swirlplates clogged and the aircraft required intensive servicing. The search for alternative solutions led to the possibility of using swirlplates that have been polished or coated in an attempt to reduce the coking rates. Several swirlplate surface finishes were investigated.

FINITE ELEMENT MODELING OF SANDWICH COMPOSITE STRUCTURES SUBJECT TO LOW VELOCITY IMPACT AND DELAMINATION

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Two common concerns in the use of sandwich composite construction are the effects of low velocity impact and delamination upon structural failure. Finite element analysis of these events can provide a comprehensive time history of the resulting stress, strain, and displacement as all points in a structure. The purpose of this research is to develop a fem model of a sandwich composite and use this model to analyze the dynamic response of various sandwich configurations subject to low velocity impact. In particular, strain vs time history, failure location mode, and the influence of an existing delamination are investigated.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

AN OPTIMIZATION TECHNIQUE USING THE FINITE ELEMENT METHOD AND ORTHOGONAL ARRAYS

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The objective of this research was to develop an optimization technique that can be used interactively by design engineers to approach an optimal design with minimal computational effort. The technique can be applied to both continuous and discrete values of design variables. A large number of design variables can be also considered.

In order to meet the objective, an optimization procedure was developed by coupling the finite element analysis (FEA) to the orthogonal array experimentation technique, because FEA is a common analysis tool for design engineers. From the results of the FEA and an orthogonal array, an average Jacobian matrix was constructed that showed the average overall sensitivity of the design variables. These sensitivities were then used to optimize the design parameters. The process could then be repeated at the discretion of the engineer until a satisfactory design is obtained. In general, the designer can predict and control the number of FEA calculations before an optimization process so that one can plan a budget and time for an optimal design.

Some examples of structural optimization with truss and frame structures with continuous and discrete values of design variables were studied using the technique developed in this paper. Their optimal solutions were found with small numbers of iterations.

EXPERIMENTAL INVESTIGATION OF FLOW CONTROL BY MEANS OF AIRFOIL FLAPPING

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Flapping airfoils generate thrust-producing jet-like wakes. It therefore is the objective of this investigation to explore whether this feature can be used for effective flow control. To this end, the flow characteristics of flapping airfoils are first explored in a water tunnel experiment, using dye flow visualization and laser-Doppler velocimeter. The effect of airfoil flapping frequency and amplitude of oscillation and of flow velocity on the wake flow characteristics are determined. This is followed by a second water tunnel experiment, where a small flapping airfoil is mounted in and near the separated flow region caused by the flow over a backward-facing step. The effect of airfoil size, location, frequency, and amplitude of oscillation on the separated flow region is again determined by means of laser-Doppler velocimeter. It is found that the reattachment length of the separated flow region can be reduced by as much as 70%.

ANALYSIS OF THE DIVETRACKER ACOUSTICAL NAVIGATION SYSTEM FOR THE NPS AUV

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Autonomous Underwater Vehicles (AUVs) require an accurate navigation system for operating in mine fields located in the near surf zone very shallow water. This research project examined the precision, performance characteristics, and reliability of a low cost, commercially produced, acoustical navigation system called “DiveTracker”. The DiveTracker acoustical navigation system provides both an acoustical short baseline operator and the AUV with position data on a

1 hertz update rate. Experiments conducted on the DiveTracker system included static and dynamic tests which examined the system's ability to accurately measure distances and track a moving AUV under water.